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Hamann et al.

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(54) **IRRIGATION SYSTEM AND METHOD**

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(58) **Field of Classification Search**

CPC B05B 12/04; A01G 25/16; A01G 25/162; A01G 25/165; A01G 25/02
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See application file for complete search history.

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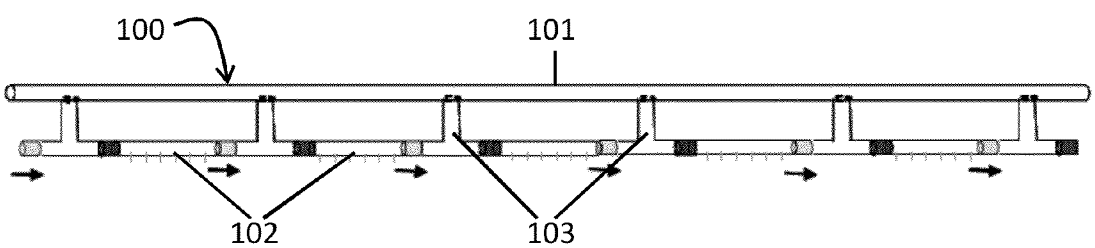
(57) **ABSTRACT**

A method of operating an irrigation system is provided and includes coupling one or more lateral driplines to a main irrigation line, dividing each lateral dripline into zones and providing each lateral dripline with a plurality of replaceable emitters at each zone, disposing a plurality of controllable valves along each of the one or more lateral driplines at zone borders and actuating each one of the plurality of controllable valves to thereby activate corresponding emitters in the associated zone.

13 Claims, 6 Drawing Sheets



(51) **Int. Cl.**
A01G 25/16 (2006.01)
B05B 12/04 (2006.01)

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FIG. 1

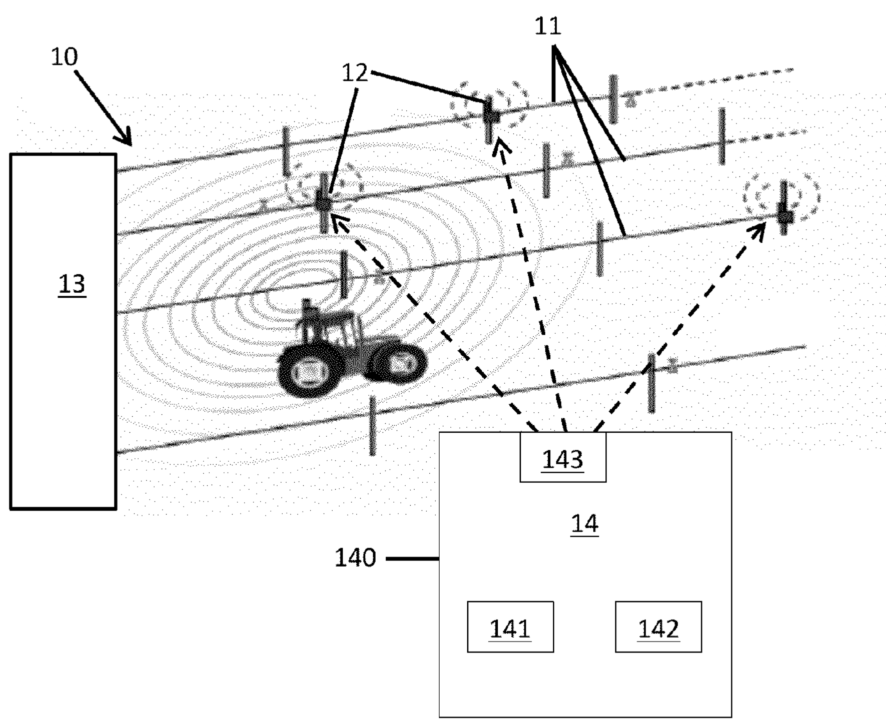


FIG. 2A

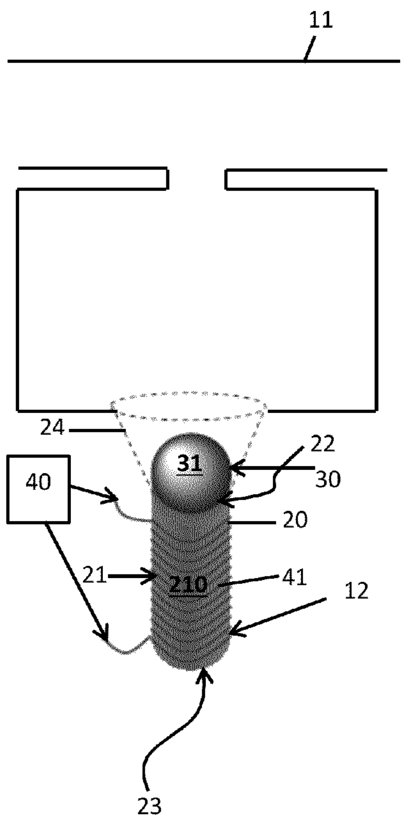


FIG. 2B

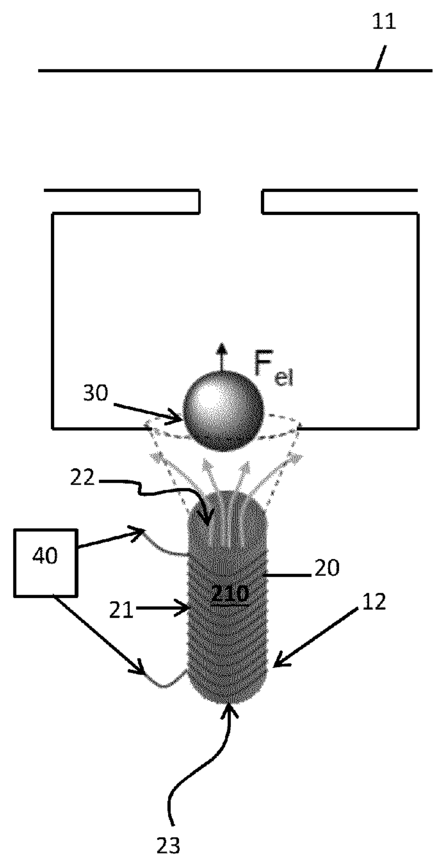


FIG. 3

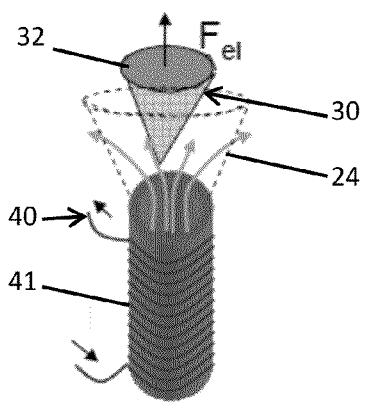


FIG. 4

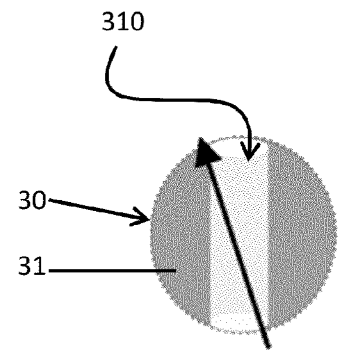


FIG. 5

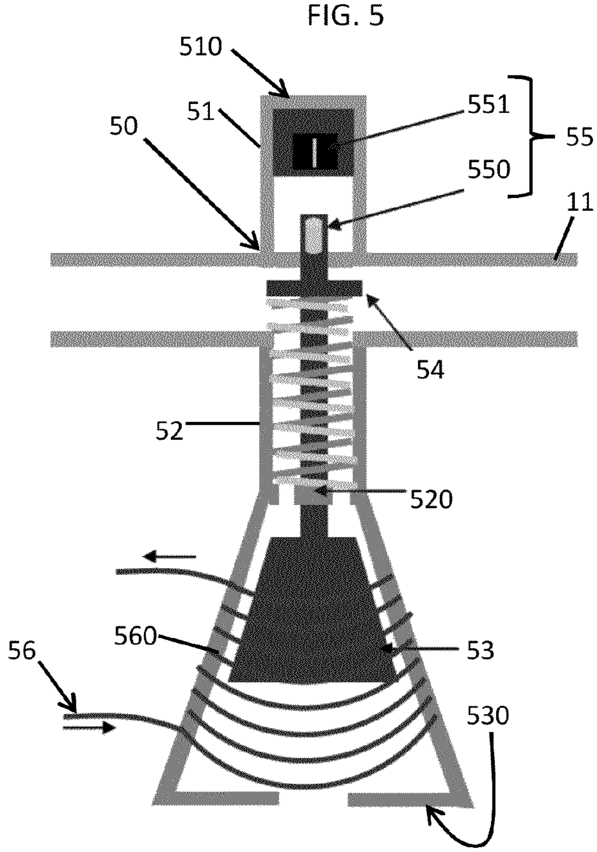


FIG. 6

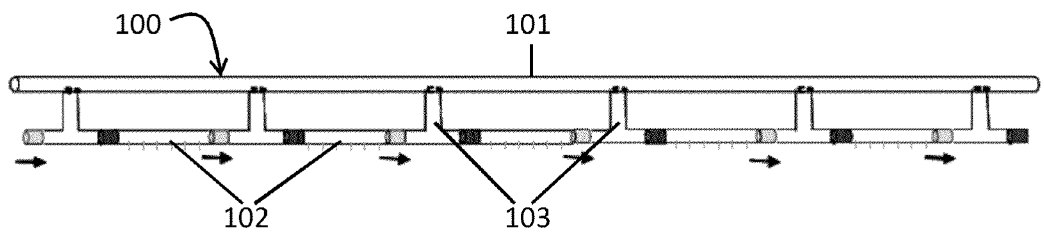


FIG. 7

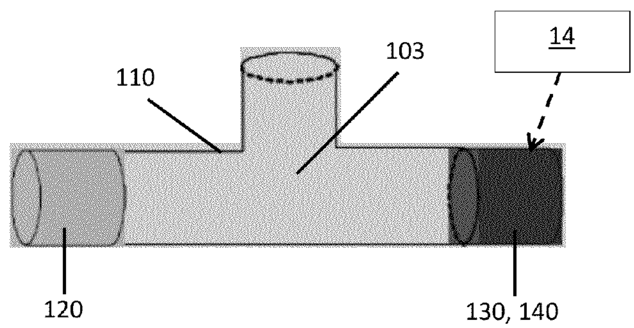


FIG. 8A

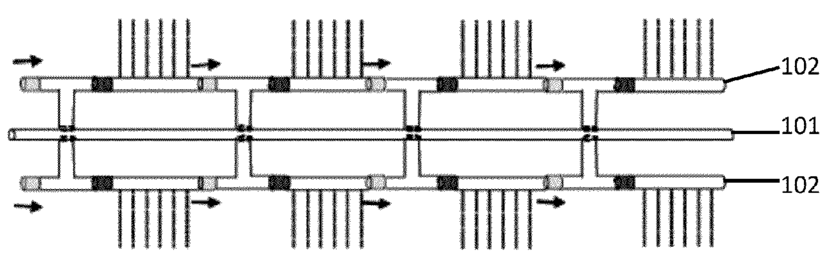


FIG. 8B

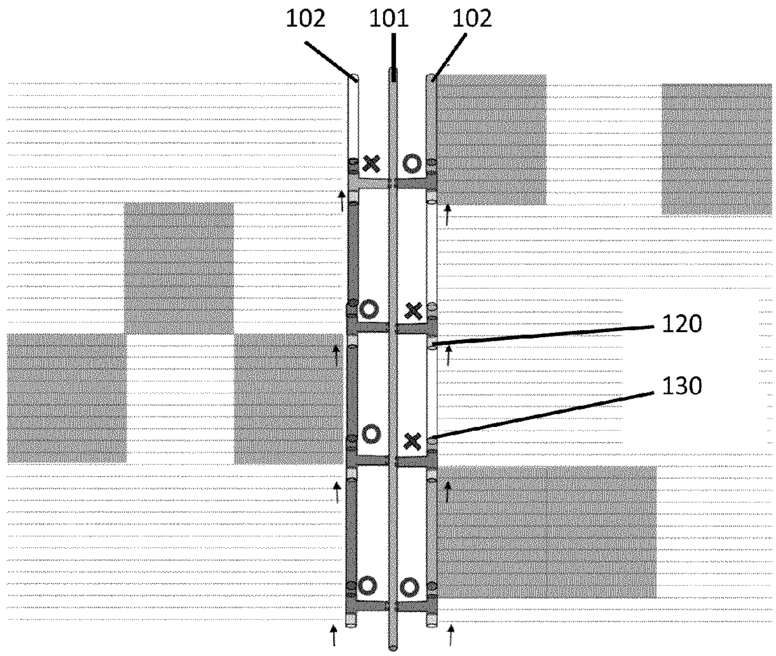
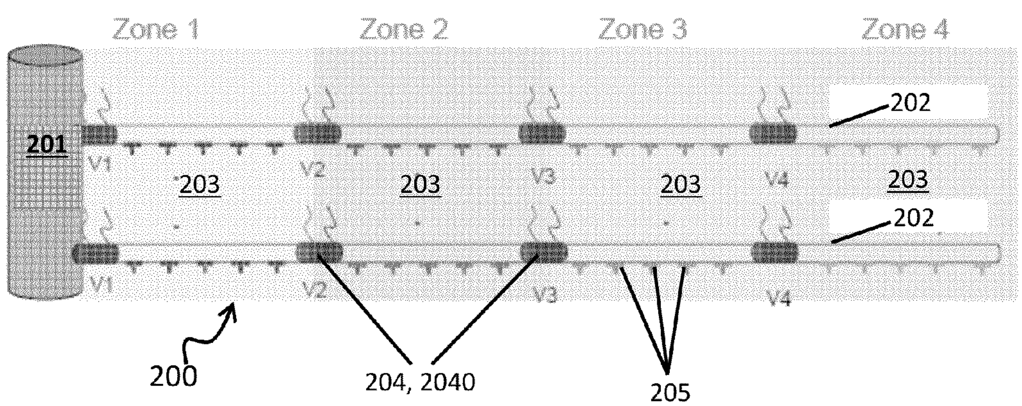

102
101
102
120
130

FIG. 9A


Zone 1
Zone 2
Zone 3
Zone 4
201
202
203
203
203
203
202
V1
V2
V3
V4
V1
V2
V3
V4
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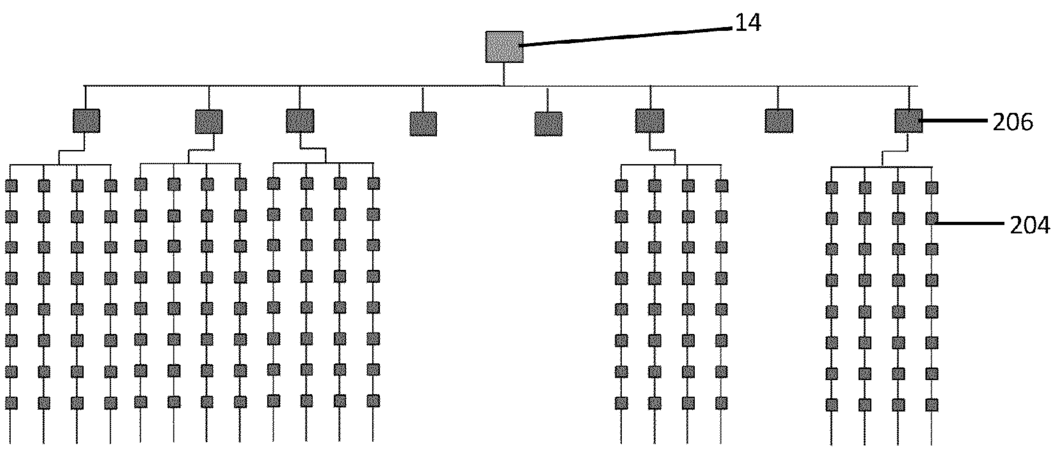
204, 2040
205

FIG. 9B



IRRIGATION SYSTEM AND METHOD

CROSS REFERENCE TO RELATED APPLICATION

This application is a Continuation Application of U.S. Non-Provisional application Ser. No. 13/792,757 filed Mar. 11, 2013, the disclosures of which are incorporated by reference herein in their entireties.

BACKGROUND

The present invention relates to an irrigation system and method and, more specifically, to an irrigation system and method in which lateral driplines are divided into zones with a plurality of emitters that are activated in a zone by zone cycle.

Current drip irrigation systems are often equipped with pressure compensated emitters that can deliver a certain amount of water to nearby areas based on the fabrication characteristics of the emitters. Typically, the emitters will have a watering rate of 0.5, 1 or 2 gallons per hour delivery. The amount is set in the fabrication process or they can be set manually in the field. This can present problems, however, because industry frequently demands that drip irrigation systems be able to dynamically adjust the amount of water that is delivered to a specific location based on real time information (satellite imagery, field deployed soil moisture sensor, thermal imagery) of the water absorbed/transpired by canopy and water evaporation from soil or soil water rentention properties.

Current approaches to the problem of using emitters with a predefined watering rate in a drip irrigation system in which dynamic adjustments are required rely on delivery of the same amount of water in every location where the amount of water is defined as the upper amount required by the most water demanding spot. The inherent differences in soil properties and crop characteristics can thus lead to overwatering in many locations based on such uniform water delivery. Potentially, different rate emitters can be installed in different locations but temporal changes in the irrigation schedule does not permit dynamic adjustments over time.

SUMMARY

According to one embodiment of the present invention, an irrigation system is provided and includes a main irrigation line, one or more lateral driplines, each lateral dripline being divided into zones and including a plurality of emitters at each zone and a plurality of controllable valves disposed along each of the one or more lateral driplines at zone borders. Each one of the plurality of controllable valves is actuatable to activate corresponding emitters in the associated zone in a zone by zone cycle and each one of the plurality of emitters is replaceable to vary an amount of deliverable fluid by the zone by zone cycle.

According to another embodiment, an irrigation system is provided and includes a main irrigation line, one or more lateral driplines, each lateral dripline being divided into zones and including a plurality of emitters at each zone and a plurality of controllable valves disposed along each of the one or more lateral driplines at zone borders. Each one of the plurality of controllable valves is actuatable to activate corresponding emitters in the associated zone in a zone by zone cycle. Each one of the plurality of emitters at each zone is replaceable by another emitter with a different emission rate such that a variable amount of water can be delivered to by the zone by zone cycle.

According to yet another embodiment, a method of operating an irrigation system is provided. The method includes coupling one or more lateral driplines to a main irrigation line, dividing each lateral dripline into zones and providing each lateral dripline with a plurality of replaceable emitters at each zone, disposing a plurality of controllable valves along each of the one or more lateral driplines at zone borders and actuating each one of the plurality of controllable valves to thereby activate corresponding emitters in the associated zone.

Additional features and advantages are realized through the techniques of the present invention. Other embodiments and aspects of the invention are described in detail herein and are considered a part of the claimed invention. For a better understanding of the invention with the advantages and the features, refer to the description and to the drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The subject matter which is regarded as the invention is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The forgoing and other features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. **1** is a schematic view of a drip irrigation system;

FIG. **2**A is a side view of a controllable emitter with a solenoid coil and a magnetic stopper in accordance with embodiments;

FIG. **2**B is a side view of a controllable emitter with a solenoid coil and a magnetic stopper in accordance with embodiments;

FIG. **3** is a perspective view of a magnetic stopper in accordance with alternative embodiments; and

FIG. **4** is a schematic illustration of a magnetic stopper in accordance with further alternative embodiments;

FIG. **5** is a side view of a controllable emitter with a solenoid coil and a magnetic stopper in accordance with alternative embodiments;

FIG. **6** is a side schematic view of an irrigation system in accordance with alternative embodiments;

FIG. **7** is an enlarged side view of a T-junction of the irrigation system of FIG. **6**;

FIG. **8**A is a side schematic view of an irrigation system in accordance with further alternative embodiments;

FIG. **8**B is a top down view of an irrigation system;

FIG. **9**A is a schematic view of an irrigation system in accordance with alternative embodiments; and

FIG. **9**B is a schematic view of a hierarchy of irrigation system control in accordance with embodiments.

DETAILED DESCRIPTION

A controllable emitter is provided. The controllable emitter can be deployed in, for example, a drip irrigation system and allows a variable of amount of water to be delivered to a specific location of the drip irrigation system over a period of time. The controllable emitter includes a solenoid coil slid over a tubular element that drips the water. The upper part of the tubular element is normally blocked by a magnetic stopper in the shape of a sphere or a cone. When a current is applied to the solenoid coil, the solenoid coil creates a magnetic field that forces the magnetic stopper to move out of the blocking position and thereby allows water to flow through the tube. The current applied to the solenoid coil can be direct current (DC), such that the magnetic stopper may be displaced continuously, or alternating current (AC), such that the magnetic stopper may be displaced periodically. The solenoid coil may be electrically coupled to an electronic circuit that contains a microcontroller that can receive a command from an external device and a memory unit on which schedule and timing information of the magnetic stopper movement is stored. Each controllable emitter of a given drip irrigation system can be addressed individually and a specific schedule can be uploaded wirelessly or over a wireless network into the memory unit such that each emitter can have an independent schedule. By keeping the magnetic stopper in a position where water can flow through the tubular element and timing the period it allows the water to flow combined with a feedback mechanism that measures water flow, the amount of delivered water can be determined by the microcontroller. The system will thus deliver variable amounts of water to any location subject to the drip irrigation system by uploading an individual watering schedule.

A system and method for applying variable amounts of water or fertilizer over a region, such as agricultural land, using a drip irrigation system is also provided. The system and method include installation of drip irrigation lines along a diverter line such that the water used for irrigation is allowed or restricted to pass through the lateral drip irrigation line using a T-junction. The T-junction has a solenoid valve and a check valve. The lateral drip irrigation lines can be assembled in variable length segments and the filling of the drip irrigation lines with water can be controlled using the T-junction and the diverter line. By controlling the solenoid valves, an amount of fluid, fertilizer or chemicals delivered to an associated area can be controlled by adjusting the time the solenoid valves are open and knowing the number of corresponding emitters and their respective emission rates.

In addition, an automated method of controlling valves to apply variable amounts of water or fertilizer over an extended agricultural land is provided and uses a minimized modification to an existing dripline system. The method takes advantage of the concept that the same amount of water from a central line can be delivered either by using emitters/nozzles that have higher emission rates (gallons per hour) and requiring less watering time or extending the watering time of emitter/nozzles that have lower emission rates. The approach proposes to install on/off solenoid valves along a dripline to control water flow and using emitters that have different emission rates along the line. The higher emission rate emitters/nozzles are positioned farther from the main water distribution line while smaller emission rate emitters/nozzles will be closer to the main water distribution line. The emitters are inserted such that their emission rate increases from low to high along the line with the low emission rate emitters being positioned closer to the main water distribution line. Thus, by controlling the solenoid valve open/closed position for different periods of time, the amount of water delivered to a specific location can be increased or decreased.

In all embodiments described above, power can be derived from a power line or form solar paneling. Certain aspects of the timing may be affected and determined by the availability and costs of such power.

With reference now to FIG. **1**, an exemplary drip irrigation system **10** is provided. The drip irrigation system **10** may be deployed over a relatively large area, such as a farm or a field that requires a predefined amount of water delivery above and beyond the amount provided as atmospheric accumulation. The drip irrigation system **10** may include multiple drip lines **11**, a plurality of emitters that can be controllable emitters **12** disposed along each of the multiple drip lines **11**, a fluid source **13** and a control station **14**. Each of the multiple drip lines **11** is fluidly coupled to the fluid source **13** wherein the fluid source **13** provides a fluid, such as water, to each of the multiple drip lines **11** as a pressurized fluid.

The provision of pressurized fluid to each of the multiple drip lines **11** may, in some cases, be pressure controlled while the plurality of emitters (i.e., the controllable emitters **12**) can be pressure compensated.

The control station **14** may be embodied as a computing device **140** having a processing unit **141**, memory units **142** and an actuator unit **143**. The processing unit **141** may be electrically coupled via the actuator unit **143** to each of the plurality of controllable emitters **12** distributed across the field to thereby provide for effective local control commands to the controllable emitters **12**. The processing unit **141** is thus configured to cause each of the plurality of controllable emitters **12** to be actuated and to allow the pressurized fluid to drip independently of one another. The memory units **142** have instructions stored thereon, which, when executed, cause the processing unit **141** to operate in accordance with the methods described herein.

With reference to FIGS. **2**A and **2**B, each of the plurality of controllable emitters **12** may include a container **20**, which is fluidly coupled to the corresponding drip line **11**, a magnetic stopper **30** and a controllable actuator **40**. The container **20** includes a body **21** that is formed as a tubular element to define an interior **210**, an inlet **22** through which the pressurized fluid is receivable in the interior **210** from the corresponding drip line **11** and an outlet **23** through which the pressurized fluid is exhaustible from the interior **210**. As shown in FIGS. **2**A and **2**B, the corresponding drip line **11** may be disposed in a substantially horizontal orientation (i.e., it extends along a plane of the irrigated region) wherein the container **20** extends in a substantially vertical (i.e., downward) orientation.

The magnetic stopper **30** is normally disposable in a first position (see FIG. **2**A) such that the magnetic stopper **30** prevents a flow of the pressurized fluid through the inlet **22** and the outlet **23**. The magnetic stopper **30** is also actively disposable in a second position (see FIG. **2**B) such that the magnetic stopper **30** permits the flow of the pressurized fluid through the inlet **22** and the outlet **23**. That is, in the embodiment of FIGS. **2**A and **2**B, the magnetic stopper **30** experiences a downward pressure due to the pressurized fluid and a gravitational force in the substantially vertical direction. Thus, with the container **20** extending substantially vertically downwardly from the corresponding drip line **11**, the magnetic stopper **30** normally sits in the inlet **22**. In this condition, the magnetic stopper **30** has sufficient size (i.e., diameter) to block the flow of the pressurized fluid through the inlet **22** and the outlet **23**. However, when the magnetic stopper **30** is urged to move toward the second position, the magnetic stopper **30** ceases to block the flow of the pressurized fluid through the inlet **22** and the outlet **23**.

With reference to FIGS. **2**A, **2**B, **3** and **4**, the magnetic stopper **30** may be provided in various shapes and sizes. For example, as shown in FIGS. **2**A and **2**B, the magnetic stopper **30** may be a spherical ball-shaped element **31** formed of ferro-magnetic material. As another example, as shown in FIG. **3**, the magnetic stopper **30** may be a conical element **32** formed of ferro-magnetic materials. In each case, the container **20** may further include a porous support element **24** that is coupled to the body **21** at the inlet **22**. The porous support element **24** may be substantially frusto-conical and serves to maintain a lateral position of the magnetic stopper **30** when the magnetic stopper **30** is urged to move toward the second position so that the magnetic stopper **30** can be reliably returned to the first position.

As yet another example, as shown in FIG. **4**, the magnetic stopper **30** may be a spherical ball-shaped element **31**, which is formed to define a bore-hole **310**. The bore-hole **310** extends from one side of the spherical ball-shaped element **31** to the other and may be sufficiently sized to sit in the inlet **22**. In this embodiment, the first position of the magnetic stopper **30** is characterized in that the axis of the bore-hole **310** is miss-aligned with respect to the axis of the container **20** and the magnetization of the material of the magnetic stopper **30** such that flow of the pressurized fluid through the inlet **22** and the outlet **23** is blocked. Due to the position and sizing of the spherical ball-shaped element **31** with the bore-hole **310**, the magnetic stopper normally assumes the first position. The second position is characterized in that the axis of the bore-hole **310** is aligned with respect to the axis of the container **20** such that the flow through the inlet **22** and the outlet **23** is permitted.

The controllable actuator **40** is configured to generate a magnetic field, which is operable to urge the magnetic stopper **30** to move from the first position to the second position (as in the embodiments of FIGS. **2**A, **2**B and **3**) or to urge the magnetic stopper to rotate from the first position to the second position (as in the embodiment of FIG. **4**). The rotation is caused by the interplay between the fluidic forces that tries to move water through the bore-hole **310** and the electro-magnetic force that tries to align the stopper magnetization with the magnetic field created by the solenoid coil **41**. In accordance with embodiments, the controllable actuator **40** may include a solenoid coil **41**, which is formed of a conductive element that is electrically coupled to the processing unit **141**. The solenoid coil **41** is supportively coupled to the container **20** and, where the body **21** of the container **20** is formed as the tubular element, the solenoid coil **41** may be slid around the outer circumference of the body **21**.

With this construction, the processing unit **141** of the control station **14** may be configured to apply current to the solenoid coil **41**. This current generates the above-noted magnetic field, which interacts with the magnetic stopper **30** to cause the magnetic stopper to move (or rotate) from the first position to the second position. The processing unit **141** may execute this routine in accordance with a predefined schedule or current conditions (i.e., during a dry spell, the amount of time the magnetic stopper **30** is urged toward the second position is increased so as to permit a larger amount of the pressurized fluid to flow through the outlet **23**). Moreover, the current applied to the solenoid coil **41** may be provided as DC or AC. In the former case, the magnetic stopper **30** is continuously urged toward the second position whereas, in the latter case, the magnetic stopper **30** oscillates between the first and second positions.

In accordance with alternative embodiments and, with reference to FIG. **5**, a controllable emitter with variable rate emitter feedback (CEVREF) **50** is provided. In this case, the CEVREF **50** includes first and second containers **51** and **52** disposed on opposite sides of the corresponding drip line **11**. Again, the corresponding drip line **11** may be disposed substantially horizontally as described above with the first and second containers **51** and **52** disposed substantially vertically upwardly and downwardly from the corresponding drip line **11**, respectively. The first and second containers **51** and **52** are each provided as tubular elements, but the first container **51** may be closed at its distal end **510** whereas the second container **52** is open at its distal end **520**. The CEVREF **50** further includes a chamber **53**, a spring-loaded piston **54** and a linear displacement sensor **55**. The chamber **53** is fluidly coupled to the open end **520** of the second container **52** and has a lower surface **530** with an opening defined therein. The spring loaded piston **54** is operably disposed in the CEVREF **50** to be movable in the substantially vertical direction with respect to the corresponding drip line **11**.

The linear displacement sensor **55** is coupled to both the first container **51** and the spring-loaded piston **54** and is configured to determine a vertical position of the spring-loaded piston **54**. In accordance with embodiments, the linear displacement sensor **55** may include an encapsulated magnet **550**, which is encapsulated in the spring-loaded piston **54** and a magnetic field sensitive sensor, such as a giant magneto-resistive (GMR) sensor **551**.

With this construction, the CEVREF **50** is controllable in accordance with the readings of the linear displacement sensor **55**. That is, as the pressurized fluid flows through the corresponding drip line **11**, the pressurized fluid will push down on the spring-loaded piston **54**. Thus, the higher the flow rate of the pressurized fluid, the greater the linear displacement of the spring-loaded piston **54** and the further the encapsulated magnet **550** will be pulled from the GMR **551**. An output signal of the GMR **551** may be receivable by the control station **14** and will be calibrated as a function of sensor-magnet position. A drip rate of the CEVREF **50** is thus controllable by varying the pressure of the fluid in the corresponding drip line **11**.

In accordance with further embodiments, the spring-loaded piston **54** may be formed of magnetic material and the CEVREF **50** may further include an additional controllable actuator **56**. The controllable actuator **56** may be provided as a solenoid coil **560** that can be wrapped or slid around the outer circumference of the chamber **53**. As described above, the processing unit **141** can apply DC or AC to the solenoid coil **56** to urge the spring-loaded piston **54** formed of magnetic material toward the open end **520** of the second container **52** or the lower surface **530**. Such effect can either block the flow of the pressurized fluid out of the chamber **53** or encourage an increased amount of the pressurized fluid to flow out of the chamber **53**.

In accordance with further aspects of the invention and, with reference to FIGS. **6**-**8**A and **8**B, a drip irrigation system **100** is provided. The drip irrigation system **100** includes a diverter line **101** and drip irrigation systems that are joined together at the beginning and at the end of the drip irrigation line. The drip irrigation system **100** further includes drip irrigation lines **102**, which are similar to the drip lines **11** described above, and T-junctions **103**. The drip irrigation lines **102** are disposable substantially in parallel with the diverter line **101** and are formed to define irrigation segments along their respective longitudinal lengths. The pressurized fluid contained in the diverter line **101** is provided to the drip irrigation lines **102** and flows outwardly through irrigation holes defined in the drip irrigation lines **102**. In some cases, each of the drip irrigation lines **102** may have lengths that can be adjusted according to spatial resolution of sensing zones.

The T-junctions **103** are each interleaved between adjacent ones of the drip irrigation lines **102**. As shown in FIG. **7**, each T-junction **103** includes a three-way line **110**, which is coupled to the diverter line **101**, a check valve **120** and a controllable valve **130**. The check valve **120** is operably disposable between the three-way line **110** and a downstream end of an upstream one of the drip irrigation lines **102** to permit fluid flow in only a forward direction (see the arrows in FIG. **6**). As such, the check valve **120** prohibits fluid flow in the reverse direction wherein fluid can only flow through the drip irrigation lines **102** in the forward direction. The check valve **120** can include a simple mechanical flap that is opened/closed by fluid pressure or a spring-loaded nozzle that is actuated by the pressure of the fluid in the drip irrigation line **102**. The check valve **120** may also include a solenoid valve that is selectively opened/closed in a manner similar to the controllable valve **130** as discussed below. In any case, the check valve **120** is complemented by the controllable valve **130** that is selectively opened/closed as described below.

The controllable valve **130** is operably disposable between the three-way line **110** and an upstream end of a downstream one of the drip irrigation lines **102**. In that position, the controllable valve **130** is operable in a first mode and a second mode. In the first mode, the controllable valve **130** permits fluid flow in only the forward direction (as illustrated by the arrows in FIG. **6**). In the second mode the controllable valve **130** prevents the fluid flow in the forward direction.

In accordance with embodiments, the controllable valve **130** of each of the T-junctions **103** may include a solenoid valve **140** where the solenoid valve **140** is operably coupled to, for example the control station **14** described above. In these cases, the control station **14** is configured to apply a current to the solenoid valve **140** or not apply the current to the solenoid valve **140** such that the controllable valve **130** operates in the first mode or the second mode, respectively. The determination of whether to apply the current or not may be made by the control station **14** based on a predefined irrigation schedule defined in accordance with a predefined temporal resolution and/or historical data or current atmospheric conditions. In some cases, the control station **14** can issue commands to individual controllable valves **130** to hereby control an amount of fluid delivered to an area proximate to the corresponding controllable valves **130**.

Each of the solenoid valves **140** may be configured to acknowledge receipt of a command to open or close from the control station **14**. In addition, each of the solenoid valves **140** may be configured to report back to the control station **14** that a received command was performed or executed. Along with signls from sensors relating to current atmospheric and soil condition, these reports from the solenoid valves **140** may be employed by the control station **14** in a closed loop feedback control system.

In accordance with further embodiments and, as shown in FIGS. **8**A and **8**B, the drip irrigation lines **102** may be disposable on both sides of the diverter line **101** such that additional area can be covered by the drip irrigation system **100**. In these embodiments, multiple ones of the T-junctions **103** may be disposable at similar axial locations along the diverter line **101** and two or more drip irrigation lines **102** may be coaxial with one another at each of those similar axial locations. In the particular embodiment illustrated in FIG. **8**A, the irrigation holes of each of the drip irrigation lines **102** at any one axial location of the diverter line **101** may be oriented in opposite directions so as to spray pressurized fluid over twice the proximal area.

In any case, for any section of irrigated area associated with a particular drip irrigation line **102**, pressurized fluid will flow outwardly through the irrigation holes only when the controllable valve **130** is opened. Thus, an amount of irrigation in that section is controllable by adjusting the time the controllable valve **130** is open and knowing the number of emitters per segment and their respective emission rates. Moreover, one or more controllable valves **130** can be opened and closed at the same time such that they can have a common control cycle. In addition, the drip irrigation lines **102** may be moved across a field and the controllable valves **130** at various sections can be activated or deactivated (i.e., controllable valves **130** are identified as being activated where they have an "O" and as being deactivated where they have an "X", as shown in FIG. **8**B) at various times and for various time periods. In this way, various sections of the field can be irrigated at various intervals and by amounts of fluid that are appropriate for current conditions at those sections.

At the upstream and downstream ends of the drip irrigation lines **102**, the drip irrigation lines are coupled to the diverter line **101** and a single controllable (i.e., solenoid) valve may be provided at the far end of the diverter line **101** and would be normally closed. These valves will stop water from escaping from the drip irrigation lines **102** but will be opened when the system has to be flushed to be cleaned from debris and organic material. For flushing, a command is issued to all of the controllable valves **130** (i.e., all of the solenoid valves **140**) to stay opened and water is pumped at high pressure through the drip irrigation lines **102**.

With reference to FIGS. **9**A and **9**B, irrigation lines such as the main irrigation lines **11** and **101** described above are commonly fitted with replaceable nozzles or emitters (hereinafter referred to as "emitters") that are pressure compensated and can have the same drip rates. The typical drip rate (hereinafter referred to as "emission rate") would be between about 0.25 gph (gallons per hour) up to about 8 gph. The amount of water delivered by a system using such features can be calculated by multiplying the emission rate with time. Thus, a 2 gph emitter that is operated for 2 hours will emit the same amount of fluid as a 1 gph emitter that is operated for 4 hours. As such, the same amount of fluid can be delivered by choosing a higher emission rate emitter that is operated for a short time or by operating a lower emission rate emitter for a longer time.

In accordance with aspects of the invention, an irrigation system **200** is provided. The system **200** includes a main water supply line **201** and one or more lateral driplines **202** fluidly coupled to the main water supply line **201**. Each of the one or more driplines **202** is divided into segments (or zones) **203** that are separated from one another by a controllable valve **204**, such as a pressure regulating or solenoid valve **2040**. The controllable valve **204** can be actuated (i.e., turned on and off) by a voltage pulse issued from control station **14** similar to the manner described above.

As shown in FIG. **9**, each of the one or more driplines **202** is equipped with a plurality of emitters **205** such that each dripline **202** has a group of emitters **205** in each zone. Each emitter **205** is activated when the controllable valve **204** associated with the corresponding zone is actuated or turned on. The one or more driplines **202** are arranged such that groups of emitters **205** for each one of the driplines **202** may be provided in each zone.

The one or more driplines **202** are further arranged such that higher rate emitters **205** are disposed toward the end of the corresponding dripline **202**, which is remote from the main water supply line **201**. The lower emission rate emitters **205** are then disposed closer to the main water supply line **201**. Thus, in zone **4**, the emitters **205** have a high emission rate, in zone **3**, the emitters **205** have a medium high emission rate, in zone **2**, the emitters **205** have a medium low emission rate and, in zone **1**, the emitters **205** have a low emission rate. As such, in order to maintain a uniform amount of fluid delivered to zones **1-4**, the emitters **205** in zone **4** need to be activated for the shortest time, the emitters **205** in zone **3** need to be activated for the next shortest time, the emitters **205** in zone **2** need to be activated for the next shortest time after that and the emitters **205** in zone **1** need to be activated for the longest time. For this to occur, the controllable valves **204** (V**4**) between zones **3** and **4** need to be opened for the shortest time, the controllable valves **204** (V**3**) between zones **2** and **3** need to be opened for the next shortest time, the controllable valves **204** (V**2**) between zones **1** and **2** need to be opened for the shortest time after that and the controllable valves **204** (V**1**) between the main irrigation line **201** and zone **1** need to be opened for the longest time.

In some cases, it is to be understood that it will not be necessary or desirable to provide a uniform amount of fluid to each of the zones **1-4**. In such cases, time multiplexing may be employed to vary an amount of fluid delivered to some of the zones but not others (i.e., to provide a relatively large amount of fluid to a central area and relatively small amounts of fluid to outer areas). For example, if the controllable valves **204** in zones **1-4** have respective emission rates of 0.5, 1, 2, 4 gph, "open" time units of 8, 4, 2, 1 would be allocated to the controllable valves **204** in order to have a same amount of water delivered to zones **1-4**. Here, as noted above, the amount of time the lowest-rate controllable valve **204** is kept open is the longest in the system since fluid has to flow through that segment.

To put twice as much fluid in zone **2** with the same controllable valve **204** configuration noted above, requires a time sequence 8, 8, 2, 1. If, however, it is desired that three times as much fluid in zone **2**, it may be necessary to decrease the emission rate of the controllable valve **204** of zone **1** to 0.25 gph. Now, the sequence of controllable valves **204** will be 0.25, 1, 2, 4 and the "open" timing would be 16, 12, 2, 1.

In accordance with embodiments, different or multiple driplines **202** can be grouped together and controlled to thereby create "variable rate irrigation" zones. In such an approach, the "variable rate irrigation" zones can be created continuously based on information provided by monitoring stations that would delineate the "variable rate irrigation" zones and specify the amount of fluid needed in each corresponding location. Such feedback information can be provided by soil moisture sensors that would monitor the water content in the soil, satellite sensing to monitor the evapotranspiration of the associated canopy or canopy sensors to measure local water content. Any of the sensing approaches will have a spatial and temporal resolution determined by the detection methods and the resolution will be matched by the length of drip lines segments and by updating the irrigation schedule. For common satellite imagery like LANDSAT, the spatial resolution will be about 15 m and the temporal resolution will be 7 day.

As shown in FIG. 9B, the multiple controllable valves **204** may be coupled to the control station **14** via gateways **206**. With such a configuration, the control station **14** is provided as a master unit that is responsible for irrigation scheduling as well as other functionalities and the controllable valves **204** are slave elements subject to the control station **14**. The gateways **206** may be provided as wired or wireless elements.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one more other features, integers, steps, operations, element components, and/or groups thereof.

The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description of the present invention has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the invention. The embodiments were chosen and described in order to best explain the principles of the invention and the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.

While the preferred embodiments to the invention have been described, it will be understood that those skilled in the art, both now and in the future, may make various improvements and enhancements which fall within the scope of the claims which follow. These claims should be construed to maintain the proper protection for the invention first described.

What is claimed is:

1. A method of operating an irrigation system, the method comprising:

coupling lateral driplines to a main irrigation line;

dividing each of the lateral driplines into zones such that multiple zones are formed along a respective length of each of the lateral driplines and providing each of the lateral driplines with a plurality of replaceable emitters at each of the multiple zones;

disposing a plurality of controllable valves remotely from the emitters along the respective length of each of the lateral driplines at zone borders between each of the multiple zones such that each plurality of emitters at each of the multiple zones is disposed non-inclusively between sequential controllable valves; and

actuating each one of the plurality of controllable valves on each of the lateral driplines to thereby activate corresponding emitters in the associated zone.

2. The method according to claim **1**, wherein the actuating comprises time-multiplexing each one of the plurality of controllable valves to vary an amount of fluid deliverable in the associated zones.

3. The method according to claim **2**, wherein the actuating further comprises replacing the emitters in one or more zones.

4. The method according to claim **1**, further comprising selectively actuating each one of the controllable valves.

5. The method according to claim **4**, wherein the selective actuating of each one of the controllable valves is in accordance with at least one of a predefined schedule, historical data and current atmospheric conditions.

6. The method according to claim **1**, further comprising associating multiple lateral driplines with similar zones.

7. The method according to claim **1**, wherein each emitter in each zone has a similar emission rate.

8. The method according to claim **1**, wherein the emitters in zones remote from the main irrigation line have higher emission rates than emitters in zones proximate to the main irrigation line and further comprising activating the emitters in the zones remote from the main irrigation line for a shorter time than the emitters in the zones proximate to the main irrigation line.

9. A method of operating an irrigation system, the method comprising:

coupling lateral driplines to a main irrigation line;

dividing each of the lateral driplines into zones along respective lengths thereof and providing each of the lateral driplines with a replaceable emitter at each zone;

disposing a plurality of controllable valves remotely from the emitters along each of the lateral driplines at zone borders between each of the multiple zones such that each plurality of emitters at each of the multiple zones is disposed non-inclusively between sequential controllable valves; and

actuating the plurality of controllable valves along of the lateral driplines to thereby activate a corresponding emitter in each of the associated zones.

10. The method according to claim **9**, wherein the actuating comprises time-multiplexing the plurality of the controllable valves to vary an amount of fluid deliverable in the associated zone.

11. The method according to claim **10**, wherein the actuating further comprises replacing the emitter in a zone.

12. The method according to claim **9**, further comprising selectively actuating the plurality of the controllable valves.

13. The method according to claim **12**, wherein the selective actuating is in accordance with at least one of a predefined schedule, historical data and current atmospheric conditions.

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